

1 **DIGITAL DIAGNOSTIC APPARATUS**

2 **AND VISION SYSTEM WITH RELATED METHODS**

3 This application claims the benefit of U.S. Provisional Application No. 60/408,711 filed
4 September 6, 2002.

5 **Field of Invention.** This invention is primarily directed to an electronic apparatus and
6 method for identifying and quantifying objects, their dimensions, condition or their conformity to
7 specifications. It includes a sensor unit having a digital identifier or diagnostic unit. More
8 particularly, the preferred embodiment is directed to an instrument for diverse functions such as: 1)
9 determination of dimensions and conformity to specifications of parts formed of various materials,
10 2) inspection for abnormalities of a surface of flat materials including plastic, metal and woven and
11 non-woven web and sheet, 3) identification of the type or quality of surfaces of a sheet material, 4)
12 identification of the denomination of bills in a bill changer or counter and similar functions, and 5)
13 determination of the presence or absence of components in a metal, plastic or wired assembly. The
14 inventions disclosed are also applicable to other needs such as those of security and safety. For
15 example, the inventions can sense intruders into an area and detect unsafe conditions such as a fire
16 or failure of machine press operator to remove his hands from a press before it is closed.

17 In short, this invention is intended to be a low cost, fast and efficient alternative to the
18 typical "machine vision" systems as well as to many of the "sensor" market systems although it will
19 have application and uses in other fields as well. In part, the inventions disclosed and claimed
20 herein are extensions and improvements of my earlier inventions disclosed in U.S. Patent
21 Application Serial No. 09/849,831 entitled DIGITAL SPECTRAL IDENTIFIER-CONTROLLER
22 AND RELATED METHODS filed May 4, 2001 as a Continuation-In-Part application which has,
23 as a primary focus, a method of identification of plants and objects using a color spectrum.

The Prior Art. As understood, the prior art machine vision and sensor units used in production processes to identify dimensional flaws, missing parts, and improper assembly are relatively complex, intricate and expensive. They include cameras having linear or area array sensors that capture images of the part under consideration at high speeds. These images are then communicated in analog or digital form to a costly frame grabber that may be mounted in a computer such as a PC. The PC must be programmed with software so as to identify the flaws, missing parts, etc. Such software often includes various algorithms to rotate the image of the part and to make calculations regarding the part. In addition, the computer must be loaded with input data relating to design data such as the drawings and dimensions of the part under consideration. The software then reads the output of the array, (which is usually converted to digital form by the frame grabber), and compares it with the design data to check for flaws, missing parts and dimensions. Not only are these systems complex and expensive, they are believed to require considerable setup time. Representative of these systems are those sold by companies such as DVT Corporation of Norcross, GA and Cognex Corporation of Natick, Mass.

SUMMARY OF INVENTION

The present inventions are primarily directed to a less complex, low cost sensor and diagnostic apparatus that is easy to setup and maintain. The preferred embodiment includes a housing having a lens for receiving light and focusing it upon a sensor array. The pixels of sensor array receive light, generate a voltage and then communicate the magnitude of the light received by each pixel, as indicated by the developed voltage, to an analog to digital converter and then to an electronic comparator. This comparator takes the form of a logic chip with associated memory devices. Such may include the conventional microprocessor, a microcontroller, or a Digital Signal Processor (DSP), etc. These items, the array, the A-D converter and logic chip with memory,

1 comprise the basic system hardware of my vision inventions. It is expected that the cost of the
2 functional components, in volume, of this basic system may be less than ten dollars. In addition to
3 this hardware, these inventions, however, also include software that preferably takes the form of
4 one basic algorithm designed to run a relatively simple correlation calculation.

5 These inventions also include fast and efficient set up methods of using this system for the
6 purposes of identification of flaws, verification of presence or absence of components, checking the
7 dimensions of a part and of evaluating the surfaces of web materials formed plastics, woven
8 materials, non-woven materials and metal for abnormalities such as spots and tears, etc. To avoid
9 the input of data from drawings, the set up methods of my inventions focus on a “compare to
10 standard” method rather than manual input of digital data from specifications and data. For
11 example, to inspect a metal piece part for conformity, a good part is first made and checked for
12 quality by a firm’s quality control department. This checked item then becomes the standard
13 against which other parts will be compared. Thus, a good part, not data from drawings or
14 specifications, are used as the preferred standard of comparison although those skilled in the art will
15 appreciate that the diagnostic unit may well function by making comparisons from input data.

16 This “compare to standard” method includes the steps of placing a product, object or
17 surface, that is known to meet all quality standards, in front of the sensor or vision unit. Light
18 reflected from the product, object or surface passes through the lens to impinge upon the sensor
19 array, *i.e.*, a series of pixels, to produce a spatial distribution of light thereon. Each pixel thus
20 receives a portion of the spatial distribution and generates a voltage to indicate the intensity or
21 magnitude of the light reflected from a small linear portion of the object, surface or product to
22 define a spatial or linear fingerprint of the object along a line of the standard object. An output
23 reflecting the linear fingerprint of the object is communicated to a “standard” memory location of

1 the logic chip.

2 Thereafter, additional products, objects or surfaces from the population to the evaluated are
3 passed under the vision system such that subsequent fingerprints of the remainder of the population
4 are taken and placed into a different memory. The logic chip runs the software algorithm to
5 compare the spatial distribution of the standard fingerprint with the spatial distribution of the object
6 or additional products and produces an output signal from the logic chip to indicate the similarity or
7 dissimilarity between the standard and the additional objects.

8 In addition to a focus upon one or more linear segments of a part, my invention can focus on
9 an area by using an area array and running the regression analysis on the area by taking each line or
10 each column of the area in sequence. Alternatively, my inventions can focus on a point of the
11 "standard" part as well as upon a line extending across the part. The focal point focus is a method
12 of checking the quality and sufficiency of a coating at a series of points on the metal part while the
13 linear segments may continue to check dimensions, presence or absence, surface irregularities, etc.
14 As will be shown this simultaneous coating and linear verification of a part may also be
15 accomplished by the use of an area array. Importantly, the inventions of this application may be
16 combined with the inventions of application serial number 09/849,831 to simultaneously provide a
17 full color spectral comparison and a black and white or grey scale comparison.

18 When using a linear array, these inventions are not limited to single line scan on each part.
19 To the contrary, the inventions may confirm the quality of a substantial portion of the part, web or
20 sheet of material. As the part comes down the conveyor at a speed of one part or one inch per
21 second, these inventions may take a linear scan across part or web at a rate of several thousand
22 scans or lines per second and each can be compared with the "standard" fingerprint immediately.
23 As a result of multiple scans at high speeds, the quality and nature of the entirety of an object can be

1 considered.

2 Accordingly, the goals and objectives of this invention are to provide, among other things,
3 one or more of the following:

4 1) a high speed, simplistic method for identifying objects, their dimensions, condition and
5 their conformity to specifications;

6 2) a low cost system and apparatus for identifying objects, their dimensions, condition and
7 their conformity to a standard sample rather than specification data which must be manually input
8 into a PC or other memory device;

9 3) a method and a system for identifying objects and species of objects, their dimensions,
10 condition and their conformity to specifications with a minimum of setup time and programming or
11 data input;

12 4) a very accurate method and apparatus for identifying objects and species of objects, their
13 dimensions, condition and their conformity to specifications;

14 5) low cost, high speed methods and apparatus for surface inspection of web, sheet and
15 extrusions of metals, plastics woven and non-woven fabrics for tears, spots, stains, and other
16 abnormalities;

17 6) a simple, low cost, high speed minimum maintenance apparatus and method for
18 identifying, grading or selecting objects, plant and animal tissue by their spatial reflections of light;

19 7) a low cost spatial scanning, sensing and identification unit that can use common or
20 standard software for identification of objects, their dimensions, condition and their conformity to
21 specifications;

22 8) a low cost scanning and sensing device having a target or aiming system to identify an
23 object whose spatial image is being generated;

9) a light scanning and sensor unit having a digital identifier for selectively identifying and evaluating objects, plant and animal tissue of different colors for purposes of evaluation, processing, etc.

10) A light sensor and diagnostic unit that can be used to scan a point, sequential lines or an area of a object, and run a correlation analysis to confirm that the point, lines or area of the object or its surface conforms to a standard;

11) a low cost machine vision unit that eliminates the need for and cost of such items as frame grabbers, personal computers, costly data input and the creation of algorithms;

12) a low cost and fast methods of installation that can avoid or minimize data input and the creation of new algorithms;

13) a low cost security device that may be set to scan a target area or background and to identify changes in the background such as, for example, an intruder into the scanned area;

14) a lost cost safety device that may be set to scan a target area of machinery and presses and to sound an alarm or stop a press when a person's hands would be injured by the closing of the machinery or the press; and

15) a light sensor and diagnostic unit that minimizes the requirement for set up time, data or software input and relies primarily on a "compare to standard" method of part or surface diagnostics.

DESCRIPTION OF THE DRAWINGS

The manner in which these objectives and other desirable characteristics can be obtained from this invention is explained in the following specification and attached drawings in which:

Figure 1 is a block diagram depicting the major components of a preferred embodiment of the vision system illustrating its application to bill identification;

1 Figure 2 is the block diagram of Figure 1 illustrating the application of the preferred
2 embodiment to surface inspection of a web or extrusion of sheet material;

3 Figure 3 is the block diagram of Figure 1 illustrating the application of the preferred
4 embodiment to test the presence or absence of a component part (bolt) of an assembly;

5 Figure 4 is a circuit diagram of the preferred electronic schematic layout including the
6 controller or diagnostic unit which may be used in the apparatus and method for sensing and
7 machine vision; and

8 Figures 5a and 5b are charts depicting the functions of the software to be incorporated into
9 the controller.

10 **DETAIL DESCRIPTION**

11 As depicted in Figure 1, a preferred embodiment of the sensor or vision system 10
12 comprises a sensor unit 20 having a housing 22. Within the housing is a lens 28 that receives
13 reflected light from an object 26 whose identity is desired. In this alternative, the object 26 for
14 identification is a five dollar bill. The light may be natural light, or if the unit is mounted in an
15 enclosed bill changer or counter (not shown), the light may be generated by a lamp 24. The lens 28
16 focuses the reflected light from along a line 30 on the bill to a sensor or linear array 32 such as part
17 no. TSL 1301 from Texas Advanced Optoelectronic Solutions of Plano, Texas. This unit has 102
18 pixels, each of which comprises a PN junction. In operation, each of these pixels develops a
19 voltage that correlates to the quantity or intensity of a spatial segment of light reflected from along
20 the line 30 on the five dollar bill. The magnitude of the developed voltage of each pixel can be read
21 by a logic chip, controller or comparator 36 such as a microprocessor, microcontroller, or preferably
22 a Digital Signal Processor (DSP), such as DSP Model No TM320F243 which is made and sold by
23 Texas Instruments of Dallas, Texas. In the first instance, a switch 94 is provided to enable the user

1 to manually instruct the logic chip 36 to pulse the sensor array 32 to obtain a spatial distribution of
2 the "standard" five dollar bill 26. This pulse signal will sequentially generate an analog output from
3 all of the pixels of the sensor array 32 and transmit them through an analog to digital converter to
4 the Controller 36 to obtain in digital format the magnitude of the voltage developed by each pixel.
5 As stated later, if the DSP Model TM320F243 is selected as the controller 36, such has a built in A-
6 D converter. The digital information or "fingerprint" of the standard is then placed into one of the
7 memory elements of the Controller or Digital Signal Processor (DSP) 36 for storage and
8 comparison purposes. When stored (memorized), the Controller or DSP 36 then has a spatial
9 distribution or "fingerprint" of the wavelengths reflected by the true five dollar bills 26 to be
10 identified as additional bills are inserted into the bill changer or counter. This first memorized print
11 thus becomes the "standard" against which subsequent fingerprints are compared. Those skilled in
12 the art will appreciate that, to insure greater, more reliable accuracy, two or more "standards" could
13 be taken of the five dollar bill by moving the bill to a second or third position to the right and
14 pulsing a second switch 96 to gain an additional fingerprint standard. Each "standard" would be
15 placed into a separate memory element of the Controller 36 or into additional memory element
16 associated with the Controller.

17 Thereafter, subsequent bills are placed into the bill changer or counter and they are moved
18 into the same position as that shown for the sample bill 26. Spatial distributions from these
19 subsequent bills are sequentially obtained, placed in memory, and then compared with the spatial
20 distributions of one or more samples. As will be explained, the controller or DSP 36 is
21 programmed with an algorithm to perform this comparison function.

22 To quickly obtain accurate identification of the five dollar bills inserted into a bill changer,
23 the Controller 36 is programmed to initialize reading the individual pixels of the linear sensor array

1 32 at a relatively high speed, such as once every 25 milliseconds. Thereafter, each clock pulse of
2 the clock of the Controller or DSP 36 will serially read the voltage generated by each pixel or
3 sensor to define a spatial linear image, frame or fingerprint of any subsequent bill placed into the
4 changer or counter. As with the standard, this voltage is converted to digital information and then
5 stored in other data memory locations of the Controller 36. After the sensors are read and their
6 output stored in the DSP 36, the memorized or ("standard") spatial distribution is compared with
7 the spatial distribution of that reflected by the last bill. While only a few wavelengths could be
8 compared to obtain a reasonably accurate determination of the similarity of the standard spatial
9 distribution with that of the subsequent bill, this invention uses all of the 102 pixels and resulting
10 data points made available by the TSL 1301.

11 Preferably, the comparison of the "standard" fingerprint with the subsequent spatial
12 distributions is performed by a regression analysis algorithm that is programmed into the
13 Comparator or DSP 36 or into an associated memory. Thus, as the bill is moved to the right as
14 shown in Figure 1, numerous spatial distributions of the bill will be developed by the linear array
15 32. These distributions are repeatedly obtained from the array by the comparator 36 upon initiation
16 of a clock pulse and a comparison of each new distribution is made with the standard. Since a DSP
17 can obtain these distributions and make these comparisons at a rate of several thousand per second,
18 the bill can be moved or conveyed across the lens relatively fast and yet permit sufficient
19 comparisons to determine the existence of a match between any distribution and the standard,
20 regardless of the position of the line from which the standard was taken. If the coefficient of
21 correlation between the standard spatial distribution and any of the subsequent linear spatial
22 distributions of the subsequent input bill is high or greater than the pre-set limit so as to reflect
23 similarity or identity, the Controller 36 generates an output on lead 37 to count the bill as another

1 five dollar bill or to provide change therefore or to provide a signal to initiate some other function.

2 If desired, a low cost target or aiming system can be added to the sensor unit 20 to identify
3 for the user the position of the spatial line on the bill that is about to be scanned into memory as the
4 standard. For example, a light emitting diode (LED) 38 can be placed on opposite ends of the
5 linear array 32 and light from the LED's will focus a beam 40 and mark a spot 42 on each end of
6 the spatial line from which the scan is taken. Such target spots will provide the user with visual and
7 immediate feedback that the reflecting line 30 is on the bill.

8 As suggested earlier, two or more separate "standard" reflecting lines 30 may be scanned
9 from the bill and used as a fingerprint to provide greater certainty that the bill is a five dollar bill.
10 As the bill is moved by a conveyor or roller system (not shown) to the right, additional light data
11 scans can be made and each will be compared with the "standard" scans to determine if there is a
12 similarity or identity between a line on the present bill and that of the bill from which the standard
13 was taken. If more than one standard is taken, an "and" gate (not shown) be used to couple the two
14 output signals together to insure that all subsequent five dollar bills have two lines that matched the
15 two fingerprinted standards. With the preferred DSP, several thousand comparisons could be
16 made each second and the user would notice no delay.

17 As another alternative, many Controllers 36 can be selected that have sufficient memory to
18 hold a plurality of "standard" reflection lines and such may be taken from several denominations
19 such as one dollar bills, five dollar bills and ten dollar bills. Accordingly, with each additional bill
20 that was placed in the bill changer or counter, the same correlation algorithm could be run for each
21 standard. The output of the Controller could be modified to indicate if the bill is a one, five or ten
22 dollar bill and provide appropriate change.

23 Figure 2 illustrates another application of these inventions. In this application, the invention

1 is being used to inspect a web material 44 of plastic, paper, woven or non-woven fabric or sheet
2 metal. As in the prior application, a "standard" spatial distribution is taken along the line 30 and
3 placed into the memory of the Controller 36. The material on this "standard" line is unblemished,
4 contains no imperfections and fully meets the manufacturer's specifications. After the standard is
5 placed into memory, the Controller 36 initiates the taking of additional spatial reflections as the web
6 is moved in the direction of the arrow. The Controller 36 first places the additional spatial
7 reflection in memory and then runs a similarity or regression algorithm to insure that subsequent
8 light reflections are identical to or similar to the standard distribution of reflected light. If not, an
9 output signal is emitted from the Controller 36 as on lead line 37. In addition, in this embodiment,
10 an analog scope is shown connected to the output lead 33 from the linear array 30. As long as the
11 web meets the "standard", the scope will reflect a straight horizontal line modified by the
12 uniformity of the illuminated light. However, when the web moves to the right such that the
13 reflected line 30 is over a spot 31, the reflected light will not be similar to or correlate with the
14 "standard" placed in memory. This lack of correlation will be reflected by the analog scope by a
15 decrease in voltage levels as shown at 31'. In addition, the Controller 36 connected to the output
16 line 33 of the array will emit an output signal showing a lack of correlation-and a defect in the web.

17 Figure 3 depicts another application of the inventions. This application is to test the
18 presence or absence of components, (bolts 46) of an assembly 48. In this application, a standard
19 was taken of an assembly in which two bolts 46 were properly placed in the assembly. Thereafter,
20 subsequent assemblies 48 will be conveyed under the spatial reflection line 30. When the second
21 assembly 48 reaches the spatial reflection line, the Controller 36 will emit an output signal
22 indicating a lack of similarity or correlation with the standard. Consequently and preferably, an
23 output signal will be generated by the comparator 36 to indicate the dissimilarity and an actuator

(not shown) will push the defective part off the conveyor. At the same time, the analog screen connected to lead 33 coming from the linear array 32 will show a substantial drop in voltage.

Figure 4 depicts an electronic circuit board 64 having mounted thereon a comparator such as a Digital Signal Processor (DSP) 36 that has been demonstrated to be effective for the purposes of these inventions. The circuit board 64 is provided with 5 volt power supply from an AC adapter 62. In addition to its processor structure, the DSP 36 has, onboard, a clock, an analog to digital converter, an I/O unit, and memory. In addition, this DSP also has a 232 port, expansion memory, analog expansion and I/O expansion together with a JTAG port for receiving the algorithm program and placing it into the memory of the DSP 36.

In operation, leads 66 and 68 prepare (SI) and initiating (CLK) data communication of the magnitude of the voltage contained in each of the pixels of the sensor array 32. This accumulated data is communicated to the analog-to-digital (A-D) converter of the DSP via lead 70. The A-D converter converts the analog signal to a binary digital signal and delivers the result to a memory address of the DSP 36. A timer built into the DSP 36 repeatedly generates a clock pulse to take a new fingerprint of its visual area and deliver the fingerprint or spectral distribution in binary form back to the DSP or micro-controller 36. With a proper light or lamp 24, a new fingerprint or spatial distribution can be developed on the sensor unit 32 at a rate as high as several thousand per second.

When an identified part, web, bill, etc. has been checked for quality and conformance to a desired standard, it is placed below the array 32 and the user pushes "Standard" switch 94. This action identifies the part as a "standard" and places its spatial distribution of reflected light in a first, standard or "fingerprint" memory on the DSP 36. After the "standard" is set, the unit is ready to look at and evaluate subsequent parts, bills, webs, etc. that the user wishes to identify or evaluate.

After each spatial distribution is fed into the DSP 36, it runs a preprogrammed regression

1 analysis to determine the coefficient of correlation between the spatial distribution of the
2 memorized standard and the spectral distribution of the object. The regression algorithm can easily
3 be written by those skilled in the art and loaded into the DSP 36 through the JTAG port. This
4 algorithm is a conventional regression calculation used to determine the degree of similarity of
5 linear curve defined by one set of spatial data points with the linear curve defined by another set of
6 data points. If one is looking to identify five dollar bills, the program must be designed to generate
7 an output signal whenever the coefficient of correlation is equal to or greater than a predetermined
8 value. Then the DSP 36 emits an output signal through the DSP bus to the I/O expansion board
9 which closes a “normally” open switch to lead 37 that activates an LED 72 or other appropriate
10 device such as a counter or a change machine. Preferably the result of the correlation computation
11 is converted to an integer factor that is representative of the coefficient of correlation so as to
12 simplify the decision and avoid a decimal number.

13 A second “standard” switch 96 can be used to set another “standard” for the five dollar bill,
14 or and the DSP can be programmed to run a second regression analysis against this standard and the
15 last spatial distribution of light received from the sensor 32. If a high coefficient of correlation
16 between each spatial distribution and each of two standards is made, such would provide greater
17 certainty that the last input bill is, in fact, a five dollar bill.

18 The pre-set value or correlation limit established for actuation of the output signal or LED’s
19 72 can be increased as desired through discriminating switches 90 and 92. The non-grounded side
20 of the more discriminating switch 90 is connected to pin 15 of the I/O expansion board. When this
21 pin is activated, the program in the controller increases the limit of the correlation coefficient by
22 $1/256$. When pin 16 of the micro-controller is activated by pressing the less discriminating switch
23 92 the correlation coefficient limit is decreased by $1/256$. The increment value, $1/256$, may be

1 decreased by a software change for greater accuracy.

2 To facilitate one's understanding of this invention, the flow chart of Figures 5a and 5b
3 further discloses the functions of the software of the Controller 36 as described herein. Users of
4 controllers and DSP will know or have available from the manufacturer knowledge of the set-up
5 routines to initiate the each of the logic chips that might be used as the controller 36. Thereafter,
6 the steps of the program to be written for each alternative device are set forth in the flow chart.

7 **ALTERNATIVE EMBODIMENTS, MODES AND METHODS.**

8 Persons skilled in the art will appreciate that the disclosed scanning and identification
9 invention can be utilized in several ways and is not limited to a specific mode. In addition, the
10 present invention can take many forms and utilize numerous components that perform in
11 substantially the same way to achieve substantially the same result. For example, numerous
12 controllers or digital identifiers could be used in lieu of the preferred DSP disclosed in this
13 specification. Those skilled in the art will appreciate that the essential functions of the digital
14 diagnostic unit or controller 36 are those of providing memory for the storage of the spatial data and
15 of the program steps reflecting the desired functions as well as logic circuitry having the ability to
16 perform the desired functions and comparison. Such may include the identified chips which have a
17 CPU and an arithmetic logic unit or its equivalent. In addition, the digital identifier 36 should have
18 an Input/Output (I/O) capacity to receive data from the sensor array and to control at least one
19 peripheral device such as the sensor array 20. Consequently, any of the various microcontrollers,
20 computers, microprocessors and digital signal processors (DSP) that have the necessary
21 components will be acceptable alternatives and may be considered for the specific application of the
22 user. Alternatively these individual devices such as the memory and I/O devices can be purchased
23 separately and wired together on a circuit board to accomplish the necessary functions. Indeed, the

1 comparators or controllers of these inventions can be obtained at a low cost so as to avoid the need
2 for investment in frame grabbers, Personal Computers or other complex systems. Moreover, other
3 devices can be selected for greater speed. For example, TM320f2820 from Texas Instruments Inc.
4 is several times faster than the TMS 320f243 and, on information, could make several thousand line
5 scans and comparisons of a surface per second.

6 In addition to the use of alternative processors, those skilled in the art will appreciate that
7 different lamps may be utilized and that in many cases, the lamp will not be necessary with natural
8 light being sufficient. Too, alternative array devices that are more sensitive or have different pixel
9 counts may be utilized instead of the TSL 1301. For example, TSL 1401 from Texas Instruments,
10 Inc. of Dallas, Texas will permit the collection of 128 wavelength sectors rather than 102. And
11 though the invention preferably uses a regression analysis to develop a coefficient of correlation, the
12 invention may well provide the desired accuracy of object identification by merely comparing only
13 three or four data points of the spatial light pattern. This could be accomplished by use of 3 or 4
14 discrete sensors properly located to sense the desired wavelengths of light and a simple comparison
15 program that does not require a regression analysis or computation of the coefficient of correlation.
16 A multiplicity of linear arrays or an area array, could be used to reduce the number of sensor units,
17 with each column representing spectral information equivalent to one sensor unit. Those skilled in
18 the art will also appreciate that, for purposes of this invention, CCD arrays will generally be
19 equivalent to CMOS arrays with the CMOS devices being faster, but somewhat less accurate.

20 In another alternative, the light source 24 of Figure 1 may be replaced by a set of multi-
21 color lamps such as a red, green, blue and near infrared. The DSP could be programmed to turn
22 on and off each lamp separately and digitize four images, one with reflected spatial distribution
23 of light with each different lamp color. When the standard switch is activated, the DSP stores

1 each spatial distribution as a standard in a separate memory location of the DSP or in additional
2 associated memory. Future spatial distributions using all four colors from additional objects are
3 compared to each standard using the regression analysis or a simple algorithm. The resulting
4 analysis thus brings color into the diagnostic role of this invention. A decision could be made if
5 any one of the four object spatial distributions provided a high correlation coefficient or
6 comparison with any one or more of the four colored standard spatial distributions.
7 Alternatively, the DSP could be programmed to require that there be a high correlation
8 coefficient for all of the four color distributions before a positive output signal is activated.

9 Alternatively, the DSP could be programmed to add the four standard spatial distributions
10 of each of the separate colors together to provide 4 times 102 or 408 data points and additional
11 objects can be evaluated by a correlation analysis between the 408 data points of the standard and
12 the 408 data points of the additional objects.

13 In yet another alternative, the imager 32 of Figure 1 could be replaced with a color linear
14 array such as KLI-2113 Tri-Linear Color Array Sensor manufactured and sold by the Eastman
15 Kodak Company of Rochester, N.Y. Such would also provide the ability to include color in the
16 discriminating process along a line. These arrays have three rows of photo elements and each is
17 covered with red, green or blue filter strips for spectral separation. In addition, each row has a
18 separate output and would use three of the digital converter inputs of the DSP. The logic and
19 comparison are the same as described above. As persons skilled in the art will appreciate, other
20 filters, such as a rainbow filter, can be used with the wide choices of linear arrays to also obtain
21 spectral information. Alternatively, those skilled in the art will appreciate that the sensor unit 20
22 of my prior application, no. 09/849,831, further identified above, can also be operated in
23 conjunction with a controller 36 of the present disclosure to add a spectral, color identification of

1 an object to the spatial identification of the present disclosure. Under such a combination, both
2 sensors would be tied to the controller 36 and it would be programmed to receive a standard
3 spectral distribution as well as a standard spatial distribution and to run sequential correlation
4 routines with the spectral and the spatial distributions.

5 Those skilled in the art will also appreciate that the controller 36 or the DSP can be
6 programmed to run the correlation analysis in different ways. For example, the controller can
7 programmed to run the correlation algorithm with on some or all of the data points of the
8 "standard" spatial distribution and a similar selection of data points of the actual objects. Indeed,
9 in some applications, the user will find that a limited number of data points control the decision
10 making process at hand. In identifying denominations of bills of the United States, one might
11 want to focus on the spatial distributions obtained from reflections of light from the green lamp
12 or reflections through a green filter. Such provides additional spectral information that will aid
13 in the identification process. Finally, the inventions disclosed herein could be coupled with the
14 full spectral identifier of my copending application, Serial No. 09/849,831 entitled DIGITAL
15 SPECTRAL IDENTIFIER-CONTROLLER AND RELATED METHODS filed May 4, 2001 to
16 provide a combination spectral-spatial identifier.

17 Those skilled in the various arts will also appreciate that the present inventions have broad
18 uses in other diagnostic operations such as safety and security. For example, the unit could be
19 mounted adjacent to an entrance to a home with the switch 94 being activated to establish the
20 existing condition. Thereafter, if a person were to come into the view of the lens, a different spatial
21 arrangement would be disclosed by the sensor array and the comparator can be programmed to set
22 off alarms upon diagnosing a condition different from the "standard," i.e., an unauthorized entry.
23 Under such circumstances, those skilled in the art would appreciate that the standard or existing

1 condition may be changed or refreshed periodically to accommodate a change caused by shadows
2 resulting from movement of the sun or other reflected light. Similarly, the unit might be mounted
3 on a machine tool or press with the switch 94 being activated to establish that condition.
4 Thereafter, if the press were to be closed while the operator's hand was inside the press, the sensor
5 could set off an alarm or disconnect power from the press upon diagnosing a condition different
6 from the "standard" or safe condition. Indeed, other uses and modifications of this invention such
7 as these will be apparent to those of ordinary skill in the art from the contents of this application.

8 **I claim:**